Comparison of Cyclic Fatigue Resistance of Three Ni-Ti Rotary Files

Mohamed A. El-Dreny[1], Mohamed M. Ibrahim[2], Amany E. Badr[3]

Abstract:

Objective: To compare the cyclic fatigue resistance of three Ni-Ti rotary files. **Materials and Methods:** A number of forty-five different nickel titanium rotary instruments (n = 15) were used in this study. All files were used according to their manufacturers' instructions. A specially designed, custom-made cyclic fatigue testing device was used in this study. The device had a simulated curved root canal within a stainless-steel block with a 45° angle of curvature and 5 mm radius of curvature. The time to fracture (TtF) in seconds was recorded visually using stopwatch. To characterize fracture mode, fractured fragments from each group were examined using a scanning electron microscope (SEM). The collected data were analyzed using one-way analysis of variance (one-way ANOVA) and post-hoc Tukey multiple comparison test with a statistical significance at $p < 0.05$ to compare the values of time to fracture (TtF) between the tested groups. **Results:** When comparing the time to fracture among the tested instruments, One-way ANOVA test revealed that there was a statistically significant difference among the three NiTi instruments ($p < 0.05$). HyFlex EDM had the highest resistance to cyclic fatigue resistance. Scanning electron microscopy analysis showed that the fracture type of all instruments was ductile fracture. **Conclusions:** According to the results of this study, HyFlex EDM had the highest cyclic fatigue resistance among the Ni-Ti instruments.

Introduction:

Nickel-titanium (NiTi) endodontic instruments have become the most widely used instruments in root canal treatment (RCT).[1] NiTi instruments are characterized by superelasticity and shape memory, but they have an unexpected fracture during instrumentation.[2] Fracture of NiTi endodontic files during RCT can be due to cyclic fatigue and/or torsional overload.[3, 4]

Cyclic fatigue occurs due to repeated compressive and tensile stresses at the point of maximum flexure. It occurs with no signs of permanent plastic deformation in NiTi instruments, so it is unexpected.[3] The manufacturers have continuously improved the Ni-Ti endodontic instruments to decrease their cyclic fatigue fracture.[5] Consequently, there are many recent NiTi instruments in the dental market.[6] So, it is important to study the cyclic fatigue resistance of these recent NiTi instruments.

This laboratory study was intended to compare the cyclic fatigue resistance of three Ni-Ti rotary files using the time to fracture as an indication for the resistance of the instruments to cyclic fatigue. The null hypothesis was that there would be no significant difference in the cyclic fatigue resistance among the three Ni-Ti tested instruments.

Materials and Methods:

Forty-five different nickel titanium rotary instruments (n = 15) were used in this study. All files were used according to their manufacturers' instructions.

Cyclic fatigue testing:

A specially designed device was used in this study, (Figure 1). It consists of a mainframe supporting a stainless-steel block containing the artificial root canals. The artificial canals were made to have similar size and taper of each instrument. Each canal had a 45º angle of curvature and 5 mm radius of curvature. The center of curvature was 5 mm from the instrument tip.

The files were rotated inside the canals till fracture. The time to fracture (TtF) in seconds was recorded visually using stopwatch.

Scanning electron microscopy analysis:

Two fractured fragments from each group were examined under a scanning electron microscope (SEM) under different magnifications.

Statistical analysis:

Sample size calculation:

The sample size used in this study was calculated before any work using G*Power program.

The data were analyzed using the statistical package for social science (SPSS) computer program. Using Kolmogorov–Smirnov test and the homogeneity of variances (Levene's test), the time to fracture (TtF) values were normally distributed, so parametric tests were used to compare the groups.

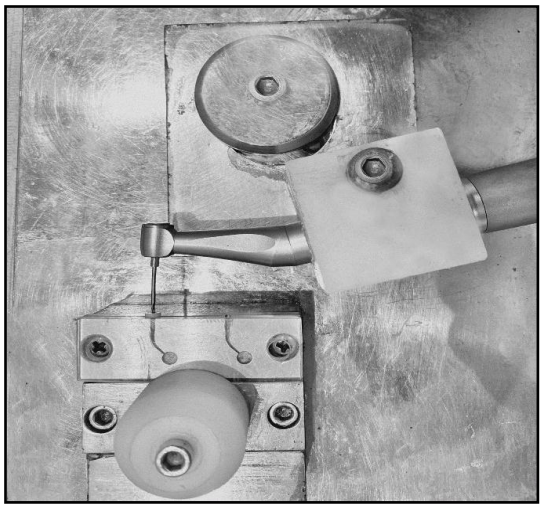

Figure 1: Cyclic fatigue testing device

[1]*Postgraduate MSc student, Department of Endodontics, Faculty of Dentistry, Mansoura University, Egypt. Corresponding author:* mosh.dreny.md@gmail.com
[2]*Lecturer, Department of Endodontics, Faculty of Dentistry, Mansoura University, Egypt.*
[3]*Professor, Department of Endodontics, Faculty of Dentistry, Mansoura University, Egypt.*
doi: 10.21608/MJD.2022.259772

Results:

The mean ± standard deviation of the cyclic fatigue test were expressed as time to fracture (TtF) in seconds, (Table). The longer time to fracture means that the tested instrument is more resistant to cyclic fatigue. One-way ANOVA test showed that there was a statistically significant difference among the three NiTi instruments ($p < 0.05$). The multiple comparison test among the three groups showed that HyFlex EDM had the highest resistance to cyclic fatigue followed by VDW.ROTATE, and TurNatomy files, respectively ($P < 0.05$).

Scanning electron microscopy:

Scanning electron microscopy analysis showed that the fracture type of all instruments was ductile fracture, (Figure 2).

Table: The values of the time to fracture of the three evaluated files

	Hyflex EDM	TurNatomy	VDW.ROTATE
TtF	636.41±107.62 a	216.36±14.33 c	421.26±46.89 b

Different letters indicate significant difference between groups

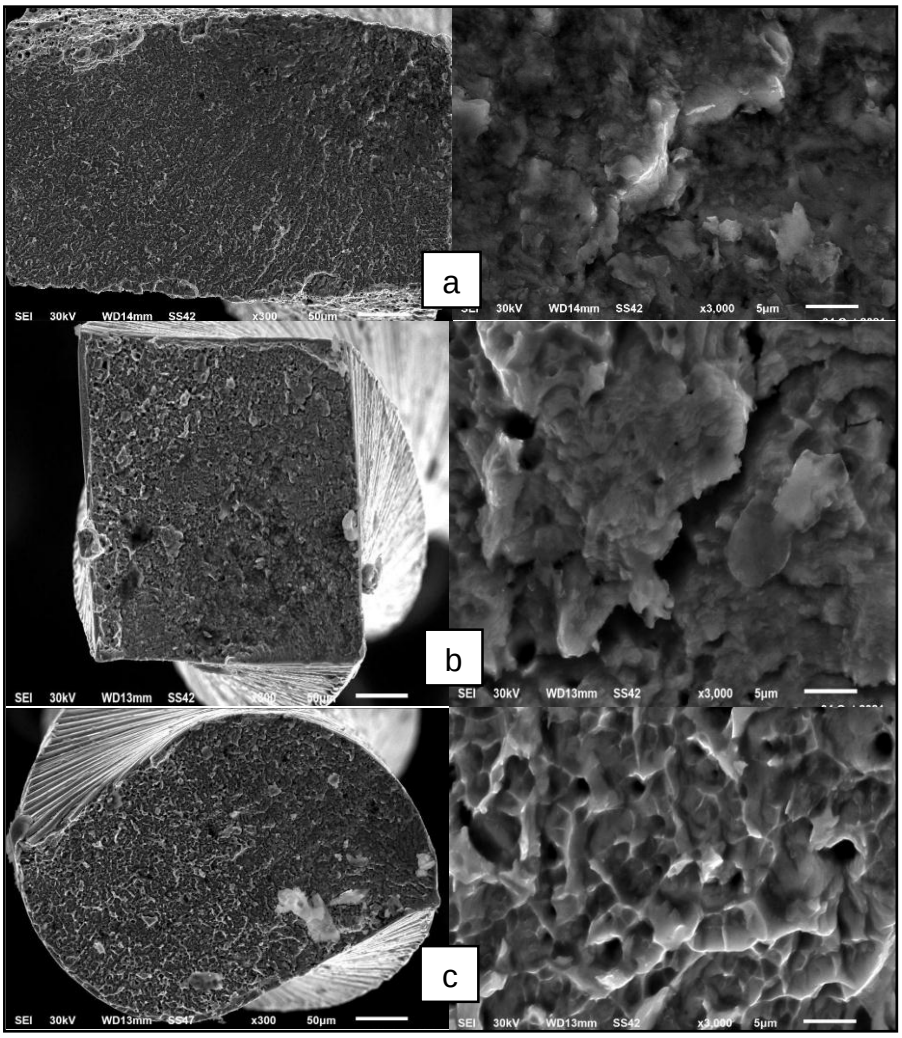

Figure 2: Scanning electron micrographs of the fractured fragments of each file group at different magnifications; (a) Hyflex EDM, (b) TurNatomy, and (c) VDW. ROTATE

Discussion:

Nickel-titanium (NiTi) endodontic instruments have become the most widely used instruments in root canal treatment (RCT).[1] NiTi instruments are characterized by superelasticity and shape memory, but they have an unexpected fracture during instrumentation.[2] Fracture of NiTi endodontic files during RCT can be due to cyclic fatigue and/or torsional stress or both.[3,4]

Cyclic fatigue occurs due to repeated compressive/tensile stresses at the point of maximum flexure. It occurs with no signs of permanent plastic deformation in NiTi instruments, so it is unexpected.[3] The manufacturers have continuously improved the Ni-

Ti endodontic instruments to decrease their cyclic fatigue fracture.[5]

The used Ni-Ti rotary files in this study were manufactured using different techniques. In this study, A custom- made cyclic fatigue testing device was used to compare resistance to cyclic fatigue of the file for standardization and to reduce variability. The artificial canals specifically designed to have similar size and taper of each of the used instruments. The cyclic fatigue fracture occurs due to incremental crack propagation caused by the cyclic stresses generated when the instruments are rotated in a curved root canal.[7] So, fractured files were examined using scanning electron microscopy (SEM) to detect the mode of fracture.

In cyclic fatigue tests, the resistance of an instrument to fracture due to the accumulation of metal fatigue induced by the tension/compression cycles at the point of maximal flexure is the variable studied. This is not typical to the clinical conditions, where a fracture is caused by a combination of variables acting simultaneously at the same time.[8] This may make it difficult to match the results of laboratory testing with a clinical condition.[8] However, it is important to assess mechanical properties of endodontic instruments in order to present valid information for the clinician.[9] So, this laboratory test represents a pure mechanical test to elicit only one property of the instruments (resistance to cyclic fatigue).

According to the results of the current study, there were statistically significant differences among the three evaluated NiTi instruments in terms of cyclic fatigue resistance ($p < 0.05$). The HyFlex EDM had the highest resistance to cyclic fatigue, followed by VDW.Rotate, and TurNatomy, respectively.

The highest cyclic fatigue resistance in the HyFlex EDM group agreed with the results of different previous studies.[11-15] This may be because HyFlex EDM files are considered the first endodontic instruments manufactured with Electrical Discharge Machining technology. EDM is a non-contact thermal erosion process used to machine electrically conductive materials by means of precisely controlled electrical discharges.[16]

According to the results in this study, the null hypothesis could be rejected. As statistically significant differences in the cyclic fatigue resistance were observed among the three evaluated files.

Methodological limitations are inherent to all in vitro studies. In the present study, it was difficult to compare the effect of a single factor on the cyclic fatigue resistance of the tested files, so trials to apply the results of this in vitro study to clinical conditions should be done with caution.

Conclusions:

HyFlex EDM had the highest cyclic fatigue resistance among the tested Ni-Ti instruments.

Acknowledgment:

Great appreciation to Prof. Dr. Amany El-Sayed Badr, Professor and Chairwoman of Endodontics Department, Faculty of Dentistry, Mansoura University and Dr. Mohamed Mahmoud Ibrahim, Lecturer of Endodontics, Department of Endodontics, Faculty of Dentistry, Mansoura University for their great help and support in this manuscript.

References:

1. Gavini G, Santos Md, Caldeira CL, Machado MEdL, Freire LG, Iglecias EF, et al. Nickel titanium instruments in endodontics: a concise review of the state of the art. J Braz Oral Res. 2018; 32.
2. Tabassum S, Zafar K, Umer F. Nickel-Titanium Rotary File Systems: What's New? Eur Endod J. 2019; 4:111-117.
3. Pedullà E, Lo Savio F, La Rosa GRM, Miccoli G, Bruno E, Rapisarda S, et al. Cyclic fatigue resistance, torsional resistance, and metallurgical characteristics of M3 Rotary and M3 Pro Gold NiTi files. Restor Dent Endod. 2018; 43:e25.
4. Ruiz-Sánchez C, Faus-Llácer V, Faus-Matoses I, Zubizarreta-Macho Á, Sauro S, Faus-Matoses V. The Influence of NiTi Alloy on the Cyclic Fatigue Resistance of Endodontic Files. J Clin Med. 2020; 9.
5. Elnaghy AM, Elsaka SE, Mandorah AO. In vitro comparison of cyclic fatigue resistance of TruNatomy in single and double curvature canals compared with different nickel-titanium rotary instruments. BMC oral health. 2020; 20:1-8.
6. Kuzekanani M. Nickel-Titanium Rotary Instruments: Development of the Single-File Systems. J Int Soc Prev Community Dent. 2018; 8:386-390.
7. Bukhari K, Almalki M, Daghestani M, Bogari D, Aljifan M, Alharbi Y, et al. Cyclic fatigue comparison of different manufactured endodontic files. Saudi Endod J. 2019; 9:186-191.
8. Silva E, Vieira VTL, Belladonna FG, Zuolo AS, Antunes HDS, Cavalcante DM, et al. Cyclic and Torsional Fatigue Resistance of XP-endo Shaper and TRUShape Instruments. J Endod. 2018; 44:168-172.
9. Hülsmann M, Donnermeyer D, Schäfer E. A critical appraisal of studies on cyclic fatigue resistance of engine-driven endodontic instruments. Int Endod J. 2019; 52:1427-1445.
10. Elnaghy AM, Elsaka SE. Laboratory comparison of the mechanical properties of TRUShape with several nickel-titanium rotary instruments. Int Endod J. 2017; 50:805-812.

11. Pedullà E, Lo Savio F, Boninelli S, Plotino G, Grande NM, La Rosa G, et al. Torsional and Cyclic Fatigue Resistance of a New Nickel-Titanium Instrument Manufactured by Electrical Discharge Machining. J Endod. 2016; 42:156-159.

12. Wang F, Yang Y, Hou X. Surface microstructure and cyclic fatigue resistance of electro discharged machining nickel-titanium endodontic instrument. J Peking Univ, Health sci. 2018; 50:876-881.

13. Rubio J, Zarzosa JI, Pallarés A. A Comparative Study of Cyclic Fatigue of 10 Different Types of Endodontic Instruments: an in Vitro Study. Acta Stomatol Croat. 2019; 53:28-36.

14. Uygun AD, Unal M, Falakaloglu S, Guven Y. Comparison of the cyclic fatigue resistance of hyflex EDM, vortex blue, protaper gold, and onecurve nickel-Titanium instruments. Niger J Clin Pract. 2020; 23:41-45.

15. Khandagale PD, Shetty PP, Makandar SD, Bapna PA, Karobari MI, Marya A, et al. Evaluation of Cyclic Fatigue of Hyflex EDM, Twisted Files, and ProTaper Gold Manufactured with Different Processes: An In Vitro Study. Int J Dent. 2021; 2021:7402658.

16. Han Y, Hou X-M. Glide path enlargement of curved molar canals using HyFlex EDM glide path file versus PathFile: a comparative study of preparation time and postoperative pain. BMC Oral Health. 2021; 21:150.